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Communicating the value of atmospheric services

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ABSTRACT: The atmosphere is one of the most valuable resources on the planet and yet because it is largely invisible it tends to be taken for granted and is increasingly being exploited and commodified. This paper presents 12 Atmospheric Services that are vital to human well-being and the existence of the biosphere. The Total Economic Value of the atmosphere is estimated to be at least between 100 and 1000 times the Gross World Product (GWP was approximately £43 Trillion in 2008). It is only by appreciating the value of the atmosphere to society that we can understand how we need to communicate sustainable management of the atmosphere and treat it as a global commons. It is also important to realize which Atmospheric Services are currently under threat. Only by appreciating the full range of services provided by the atmosphere can the real cost of geo-engineering the climate be calculated. Before geo-engineering of the climate can ever be considered seriously a Law of the Atmosphere will be required. Copyright © 2010 Royal Meteorological Society

KEY WORDS atmospheric services; geoengineering; global commons, law of the atmosphere

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1. Introduction

The atmosphere is a vital component of the Earth System and yet its immense social and economic value to society is largely ignored and taken for granted (Walker, 2007). The artist Adam Nieman (Figure 1) highlights how tiny the atmosphere, and the hydrosphere, are in comparison to the size of the Earth – and hence both are precious and in need of very careful sustainable management. Can an image such as this communicate to policy makers and the general public the fragility of these two components of the Earth System much more effectively than an academic paper?

The expression that ‘a picture is worth a thousand words’ has been used in the English language since the late nineteenth century, although its exact origins are unclear. It is frequently quoted to students and researchers as an incentive for them to illustrate their essays and research papers with pictures, figures, maps and graphs. Meteorology provides a host of examples where the visual representation (picturing theory) of how the atmosphere works helps to communicate the science (Thornes, 2008a). Weather forecast graphics, satellite pictures, weather radar and lidar images displayed in newspapers, on television, on the internet and mobile phones synthesize a huge amount of meteorological observations and modelling. In fact the original Chinese ‘proverb’ (畫意能達萬言) actually translates as ‘a picture’s meaning can express ten thousand words’. This proverb has not been handed down from antiquity, however, but rather was featured in an advertising campaign on the side of streetcars in California in the 1920s to illustrate the importance of getting a marketing message across, in a few seconds, as a streetcar passes, by: Barnard (1927).

Visual images of the atmosphere cannot provide successful communication in isolation. The visual image might attract the necessary attention but it is still necessary to back up the image with the appropriate thousands of words! Images are generated with, interpreted through and assessed by the socio-cultural framings and philosophies in contemporary society. This paper is about describing, appreciating, managing and communicating the value of atmospheric services. Costanza *et al.*’s paper (1997) on the valuation of ecosystem services opened up the potential of discussing the conservation of nature in terms of the services rendered to society. As an economic approach, this provided a communicable framework for contemporary decision-making that, frequently, relies on cost justifications. This is important given the predictions about climate change. ‘With increasing frequency and severity over the past century, human activities have reduced the atmosphere’s capacity to supply the atmospheric services upon which humans and the rest of the biosphere intimately depend’ (Harrison and Matson, 2001).

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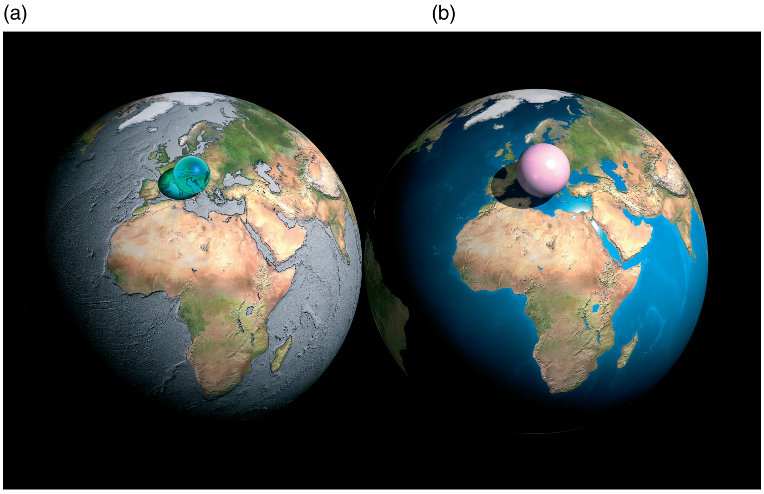

Figure 1. The fragility of the earth's hydrosphere and atmosphere (www.gatheredimages.com). Figure 1 was created by the artist Adam Nieman representing the total volume of water on Earth (a) and of air in the Earth's atmosphere (b) shown as spheres (blue and pink). The spheres show how finite water and air supplies are. The water sphere measures 1390 km across and has a volume of 1.4 billion km^3. This includes all the water in the oceans, seas, ice caps, lakes and rivers as well as ground water, and that in the atmosphere. The air sphere measures 1999 km across and weighs 5140 trillion tonnes. As the atmosphere extends from Earth it becomes less dense. Half of the air lies within the first 5 km of the atmosphere. (http://www.sciencephoto.com).

The atmosphere often hits the headlines as a hazard (climate change, floods, snow, heat waves, droughts, windstorms and tornadoes) but rarely hits the news at all as a resource or service. It is important to set the record straight. In order to appreciate the importance of the atmosphere to life on the planet it is necessary to communicate the economic value of this resource/service to everyone from governments to the general public. Society then might realize, at a time of poor air quality, ozone depletion, enhanced global warming and potential geo-engineering of the climate, that there is a need to treat more carefully the free services which the atmosphere is providing to society. If the value of this precious natural commodity can be effectively communicated then it might be possible to ensure that the atmosphere is managed sustainably as a global commons for the benefit of all life in the biosphere.

This paper looks at 12 Atmospheric Services that everyone relies upon for every minute of their existence on Earth, and that help to provide and sustain the Earth System for our human well-being. Those Atmospheric Services that are under threat are identified and the paper shows that the atmosphere has effectively a minimum total economic value of between 100 and 1000 GWP (Gross World Product).

The concept of Ecosystem Services has gained widespread acceptance and political credibility with the UN endorsed publication of the Millennium Ecosystem Assessment (2005), which defines ecosystem services as being primarily concerned with the value of the biosphere for human well-being. The value of the services provided by the atmosphere, hydrosphere and lithosphere have not yet been considered in any detail. Indeed Costanza *et al.* (1997) state: 'It is trivial to ask what is the value of the atmosphere to humankind, or what is the value of rocks and soil infrastructure as support systems. Their value is infinite in total'. However Barnes (2001) states that: 'Commonly inherited gifts of nature provide more (or at least a comparable amount of) wealth to humanity than all human efforts combined. . .A market system that values such an enormous trove of wealth at exactly zero is fundamentally flawed'.

The total value of atmospheric services is certainly somewhere between zero and infinity and this paper assesses the value of the combined components of atmospheric services for the first time. In total their replacement value may be effectively infinite (>1000 GWP) but it is certainly not trivial to identify and assess the importance of the atmosphere to humankind at a time when climate change is threatening the very existence of society. To manage the atmosphere efficiently, all its various component systems and services to human well-being must be understood. Only then can those atmospheric services that need urgent attention be identified and a proper assessment be made of what the likely consequences would be to geo-engineer or adapt to them, remembering that all the services are interlinked.

The growth in the study of ecosystem services has largely ignored the atmosphere (Costanza *et al.*, 1997; Millennium Ecosystem Assessment, 2005; Hindmarch *et al.*, 2006; Haines-Young and Potschin, 2008) indeed the actual definition and classification of ecosystem services is still widely debated (Boyd and Banzhaf, 2006; Wallace, 2007; Costanza, 2008). Costanza *et al.* (1997) did include monetary value for the role of ecosystems in the regulation of atmospheric composition, global temperature and precipitation though few details were given on how these calculations were made. Costanza *et al.* (1997) estimated the global economic value of 17 ecosystem services to be about \$33 trillion *per* year compared to the Gross World Product of around \$18 trillion *per* year (1994) at that time (approximately twice GWP). Of these 17 ecosystem services two are directly related to atmospheric services: (1) gas regulation – regulation of atmospheric chemical composition (value estimated to be \$1.3 trillion) and (2) climate regulation – regulation of global temperature, precipitation, and other biologically mediated climatic processes at global or local levels (value estimated to be \$0.7 trillion). Together these account for just over \$2 trillion or about 6% of the total. Indirectly the atmosphere is also an integral part of several of the other ecosystem services including water supply, nutrient cycling, pollination, recreation and cultural which account for more than two thirds of the remaining total. However Costanza *et al*. (1997): 'For the purpose of this analysis we grouped ecosystem services into 17 major categories...We included only renewable ecosystem services, excluding non-renewable fuels and minerals and the atmosphere'.

This is confusing as it is not clear which atmospheric services have been included and which have not. Nevertheless it is clear that the limited atmospheric services that have been included make up a significant proportion of the \$33 trillion and also that many more atmospheric services have been excluded. It is also clear that the value of atmospheric services will be significantly greater than the value of ecosystem services and that ecosystem services could not exist without the atmosphere.

In recent years the atmosphere has been presented much more as a hazard rather than as a resource and the focus has been on the adverse and costly effects of weather and climate on society: acid rain, ozone depletion, climate change, floods, droughts, heat waves, tornados, hurricanes and other severe storms. Munich (2009) has estimated that severe weather events could cost society as much as \$250 billion *per* year by 2050. Stern (2006) has suggested that if society spends 1% of GWP now, each year, on mitigating and adapting to climate change then it could potentially save between 5 and 20% of future GWP as avoided damage to society.

A cost benefit analysis, comparing these atmospheric hazards with atmospheric services, would show that the benefits of atmospheric services are of considerably greater value to society today than the costs of severe weather and climate change. However, in the future this balance might well change, especially if enhanced global warming is allowed to continue. Therefore, it is imperative to consider how the atmosphere is owned and managed (Najam, 2000; Vogler, 2001; Tickell, 2009). Currently, atmospheric services are managed in a non-sustainable piecemeal way. There is an urgent need to consider the atmosphere as a precious global entity that requires careful management. This is especially important in the light of the serious consideration of 'geo-engineering' the global climate (Royal Society, 2009). For example in the consideration of field trials for stratospheric geo-engineering using sulphate aerosol injection at least the Convention on Long-range Transboundary Air Pollution (CLRTAP) and the Vienna Convention for the Protection of the Ozone Layer (VCPOL) and the United Nations Framework Convention on Climate Change (UNFCCC) would need to be involved. A unified Law of the Atmosphere may be required.

2. The twelve atmospheric services

> You can't see it; yet the sky is blue. You can't touch it; yet you can feel its movement. It is very light and easily moved; yet it can support weights of hundreds of tons, destroy buildings and even move the Earth. It has no voice; yet conversation and music are impossible without it. It won't stop a bullet; yet it protects us from cosmic missile attack. It dries the washing; yet it brings us rain. It doesn't generate heat; yet it keeps the earth from freezing. It is non-flammable; yet it allows us to make fire. It lacks life; yet it sustains it. These are a few of the multitude of attributes of the wonderful material that is 'Air'. (Fahy, 2009)

The atmosphere is crucial for the survival of the biosphere and for human well-being. A brief summary of each of the 12 identified atmospheric services (Table I) is given below (for more detail see Thornes (2010)). Undoubtedly there are additional atmospheric services that have not been identified here but this paper presents an initial list.

2.1. The air that we breathe

Each person breathes about 15 m^3 of air *per* day converting oxygen into carbon dioxide and water vapour – the two most important greenhouse gases. Without air all of us would be dead within minutes but breathing is taken for granted. Oxygen in the atmosphere is also breathed by animals and insects. Nitrogen is also indispensable for our well being. It is one of the essential building blocks for proteins in our bodies and serves to dilute the volume of oxygen in the air, otherwise the atmosphere would burst spontaneously into flame. Clean air is considered by the World Health Organisation to be a basic requirement of human health and well-being.

2.2. Protection from radiation, plasma and meteors

The stratospheric ozone layer contains approximately 5 billion tonnes of ozone which protects us from harmful ultraviolet radiation UVB (320–290 nm) and UVC (290–100 nm). The hole in the ozone layer over Antarctica was first identified in 1985 and by 2000 it covered an area of 28.3 million km^2. There are now signs of recovery due to the banning of chlorofluorocarbons (CFCs) as part of the Montreal Protocol (Velders *et al*., 2007) but careful monitoring is still required to ensure complete restoration.

The atmosphere, together with the Earth's magnetic field, continually protects us from the solar wind (radiation plasma). The atmosphere also causes meteors to burn up before they reach the Earth's surface – although about 100 tonnes of material gets through to the Earth's surface each year.

Table I. The twelve atmospheric services.

Rank in value	Atmospheric services	Usage trend	At risk[a]	Entity	Service type
1	The air that we breathe	++	**	O_2, N_2 etc	Provisioning
2	Protection from radiation, plasma and meteors	+	**	Density, ozone layer	Supporting
3	Natural global warming of 33 °C	+	*****	CO_2, CH_4, N_2O, H_2O ++	Supporting
4	The cleansing capacity of the atmosphere and dispersion of air pollution	+	*	OH, wind, temp	Regulating
5	The redistribution of water services	+	**	H_2O	Supporting
6	Direct use of the atmosphere for ecosystems and agriculture	+	*	CO_2, N_2, filtered solar	Provisioning and supporting
7	Combustion of fuel	−		O_2	Provisioning
8	Direct use of the atmosphere for sound, communications and transport	+	*	Density, pressure	Supporting
9	Direct use of the atmosphere for power	++		Wind, wave	Provisioning
10	The extraction of atmospheric gases	+		O_2, N_2, Ar etc	Provisioning
11	Atmospheric recreation and climate tourism	+	*	Sun, wind, clouds, snow	Cultural
12	Aesthetic, spiritual and sensual properties of the atmosphere, smell and taste	+		Sky, clouds	Cultural

[a] The 'At Risk' stars are a subjective rating of the relative risk each atmospheric service currently faces due to population growth, air pollution, enhanced global warming and ozone depletion.

2.3. Natural global warming of 33 °C

Without the atmosphere the mean temperature of the Earth's surface would be about 33 °C colder (from the current 15 °C down to −18 °C). Enhanced global warming due to society polluting the atmosphere has already caused the mean global temperature to rise by about 0.8 °C since pre-industrial times. The recent COP-15 meeting in Copenhagen (December 2009) was intended to agree the global mitigation of greenhouse gas emissions to attempt to restrict enhanced global warming to 2 °C. Time will tell if this global management can be achieved.

2.4. The cleansing capacity of the atmosphere and the dispersion of air pollution

Luckily for global life and society the atmosphere has evolved a self-cleansing process, called the oxidation capacity of the atmosphere, that removes many harmful pollutants automatically. However, since the Industrial Revolution society has used the atmosphere as a waste dump to disperse a range of air pollutants which means that effectively society is 'fouling it's own nest' (Hardin, 1968). There is a raft of legislation around the world to regulate air pollution but air quality is still a problem especially in developing countries. Poor indoor air quality remains one of the key global health challenges. The World Health Organisation (2009) estimates that there are 2 million premature deaths worldwide each year caused by air pollution.

2.5. The redistribution of water services: clouds and the hydrological cycle

The requirements for fresh water are increasing every day as the global population continues to rise towards 7 billion and large developing countries such as India and China grow their economies. The hydrological cycle is a natural process that uses the atmosphere to transport fresh water around the globe to be redistributed by clouds and precipitation. Globally about 70% of available fresh water is used by agriculture to grow food and, increasingly, biofuels. Clouds play a vital role in the energy balance of the Earth's surface as well as in releasing latent heat in the atmosphere to energize our day to day weather and precipitation.

2.6. Direct use of the atmosphere for ecosystems and agriculture

The natural oxygen and carbon dioxide in the atmosphere are vital ingredients to photosynthesis and respiration which are the mainstay of all ecosystems and agriculture. Almost 100 million tonnes of nitrogen fertilizer are manufactured each year using nitrogen from the air together with hydrogen from natural gas. This inorganic fertilizer sustains, *via* food production, as many as 40% of people alive today. The global winds are responsible for regulating the upwelling of nutrients for the marine biosphere as well as contributing, with rain and frost, to the erosion of the Earth's crust, thereby replenishing soils.

2.7. Combustion of fuel

Oxygen is required for the burning of fossil fuels and wood to produce energy and electricity. All of us subconsciously rely on oxygen being available for combustion when switching on our central heating, starting our cars or flying in an aeroplane. Each day, globally, each individual consumes about 1 litre of oil, which requires about the same amount of oxygen to combust as is globally breathed each day.

2.8. Direct use of the atmosphere for sound, communications and transport

Air transport relies directly upon air density for lift in the atmosphere as well as oxygen for the combustion of fuel. There are more than 20 000 civil aircraft in service around the globe. Airspace is also required by birds and winged insects. A very important function of the atmosphere is wind pollination which is responsible for 90% of all plant pollination (Rupp, 2005). Another valuable service provided by the atmosphere for communication is sound and the propagation of speech and music as well as radio waves.

2.9. Direct use of the atmosphere for power

The most increasingly important direct source of sustainable power at the moment is wind power, but the atmosphere also plays an important role in wave power (driven by the wind), hydroelectric power (rainfall) and solar power (determined by cloud cover). Wind power could supply more than 20% of current world energy requirements by 2050 with the installation of up to 2 million windmills world wide. Air-source heat pumps are very efficient and compressed air is a convenient way of storing energy.

2.10. The extraction of atmospheric gases

There is a large global industry extracting gases from the atmosphere such as oxygen, nitrogen, argon and other rare gases to use as commodities in a huge range of industries. Air as a raw material is free to extract and does not require the permits that a mine on land or under sea would require. Interestingly there is a big growth industry in trying to develop cost effective ways to extract carbon dioxide from the atmosphere (Carbon Capture and Storage, CCS).

2.11. Atmospheric recreation and climate tourism

Almost 1 billion tourist arrivals were recorded in 2008 worldwide and tourism is now the biggest global industry. Not all tourism is weather/climate related but a large proportion of tourists are looking for warm sunshine in the summer and snow (skiing) in the winter. All outdoor sport and recreation is directly influenced by the atmosphere, and events such as gliding and sailing are totally weather dependent. Some sports such as cricket benefit from weather interference (Thornes, 1976).

2.12. Aesthetic, spiritual and sensual properties of the atmosphere

Although the atmosphere may appear to be colourless, tasteless and odourless for much of the time in fact it is vital for sensual function. Smell relies entirely upon the diffusion of thousands of different molecules, from perfume to manure, to our receptive noses. Humans have about 5 million receptor cells compared to the 200 million possessed by a dog. Taste is closely linked to smell and it is no surprise that our senses have developed to work in the atmosphere that is a part of us. The sky provides a daily delight of ephemeral environmental art (Thornes, 2008b) and artists such as Constable, Monet and Turrell have focussed on the atmosphere. The sky and the atmosphere have always been associated with the spiritual and the divine.

3. The valuation of atmospheric services

Trying to put a value on nature is extremely controversial and difficult. There is a host of papers discussing the basic principles and pitfalls (Bockstael *et al.*, 2000; Daily *et al.*, 2000; Maddison, 2001; Atkinson and Mourato, 2008). The Earth system and solar energy provide all the natural capital and services that underlie human well-being and GWP. The relative contributions of the atmosphere, biosphere, hydrosphere, lithosphere and solar energy to GWP are impossible to differentiate and value accurately.

In attempting to assess the economic value of atmospheric services a different approach can be used. The 2008 Gross World Product GWP was approximately \$70 trillion (exchange rate £1 = \$1.6) i.e. £43 trillion (CIA, 2008): for simplicity let us give it the value of 1 GWP. If the services provided by the atmosphere had to be replaced (for example by using some form of geo-engineering or by moving the Earth's population to another planet) the total economic cost would be multiple times the current value of GWP. Current estimates of the costs of stratospheric geo-engineering (Robock *et al.*, 2009) for example only consider direct costs and have not considered the huge indirect costs. Although the use of GWP for assessing the social benefit of scarce resources has been criticized by many authors (Starrett, 2003; Hulme, 2009) as being too 'materialistic' or 'completely inadequate' it nevertheless does provide a pragmatic 'yardstick' for comparison with Costanza *et al.* (1997) and Stern (2006).

The value of atmospheric services is obviously neither zero nor infinity as discussed in the Introduction. Carbon dioxide already has a virtual market value of about £10 to £12 tonne^{-1} in the EUETS (European Union Emissions Trading Scheme). In total there are approximately 3 trillion tonnes of carbon dioxide in the atmosphere which therefore has a virtual value of about £30 trillion. If the rest of the atmosphere were valued at £10 *per* tonne the 5148 trillion tonnes of atmosphere would be worth more than 1000 GWP. Table I shows that every tonne of air is providing services for human well-being whether that tonne of air is near the surface or in the upper reaches of the atmosphere. Of course this is an heuristic approach and is likely problematic given the EU's prices are based on the distribution of an artificially scarce resource, whereas all atmospheric carbon is

Table II. Likely impacts on atmospheric services of aerosol injection into the stratosphere.

	Table II atmospheric services	Likely impacts of geo-engineering using sulphate aerosol injection into the stratosphere +/−	Likely reasons (Robock, 2008)
1	The air that we breathe	−ve	$SO_2 > 100$ ppm dangerous to life and health
2	Protection from radiation, plasma and meteors	−ve	Ozone depletion and ozone holes would increase in size
3	Natural global warming of 33 °C	+ve and −ve	Reduced enhanced global warming but lack of control
4	The cleansing capacity of the atmosphere and dispersion of air pollution	−ve	More acid rain
5	The redistribution of water services	−ve	Reduced precipitation, and droughts in Africa and Asia
6	Direct use of the atmosphere for ecosystems and agriculture	+ve and −ve	Some evidence of enhanced photosynthesis and carbon capture with more diffuse solar radiation but more damage from UV and less precipitation
7	Combustion of fuel	−ve	Big energy footprint to inject SO_2 into stratosphere
8	Direct use of the atmosphere for communication and transport	−ve	Corrosion of aircraft, restricted flight paths
9	Direct use of the atmosphere for power	−ve	Significant reduction of direct solar radiation for solar power
10	The extraction of atmospheric gases	−ve	More expensive
11	Atmospheric recreation and climate tourism	−ve	Increase in sun cancer, optical astronomy ruined
12	Aesthetic, spiritual and sensual properties of the atmosphere	−ve	No more blue skies!

not scarce. However, it does provide a broad feel for the likely value of atmospheric services.

A tonne of air does not really relate to every day experience. The more common measure of air is the cubic metre (the density of air is around 1.2 kg *per* m^3 at sea level). The current market price of compressed air is about £2 *per* m^3 (British Oxygen, 2009, personal communication), although the price is much reduced for bulk purchases. What would society be 'willing to pay' for our use of the atmosphere? Let us make a conservative estimate that the atmosphere has a TEV (Total Economic Value) of somewhere between 0.1 p and 1 p *per* m^3 for all the Atmospheric Services listed in Table I. Each person on the planet breathes about 5500 m^3 of air *per* year and this would give a value of between £5.50 and £55.0 *per* year. Certainly people, even in developing countries, would recognize that £5.50 *per* year (1.5 p *per* day) for the air that they breathe, plus all the other services provided in Table I, is a bargain. Even at £55 *per* year (15 p *per* day) this would be very reasonable compared to the cost of water and land rates in developed countries. If the atmosphere is valued at between 0.1 p and 1 p *per* m^3 the whole atmosphere (4.3×10^{18} m^3) would be worth (£$4.3 \times 10^{15-16}$) which is the equivalent of between 100 and 1000 GWP.

The TEV of the 12 atmospheric services itemized in Table I is therefore estimated by two different methods to be at least somewhere between 100 and 1000 GWP which is a very low estimate as it only includes direct 'use value' by humans for Atmospheric Services.

Table I shows a ranking value for each atmospheric service. These figures are initial exploratory estimates and are only meant to give a broad idea of the importance of each service for human well-being. An interesting question to ask is how much it would cost to replace or supplement each of these vital atmospheric services using, for example, some form of geo-engineering. Boyd (2008) ranks the various geo-engineering schemes that have been proposed to mitigate climate change but cautions that many of them have unwanted and costly side-effects. Cathcart and Ćirković (2006) describe enclosing the entire Earth's atmosphere with a 'polyvalent roof' so that weather and climate become an 'air-conditioning' issue! The Royal Society (2009) has just published the report 'Geo-engineering the Climate' which looks at the current ideas for extracting carbon from the atmosphere and reducing the amount of solar radiation reaching the Earth's surface. None of these ideas have yet been effectively costed (Robock *et al*., 2009) and their total impact on the full range of atmospheric services needs to be urgently researched (Table II).

The ranking in value of each atmospheric service in Table I is subjective but important as those seven services 'at risk' include the top six in terms of economic value and importance to human well-being. The rating of the 'at risk' services is also subjective but shows that more than half of the identified atmospheric services are at risk. Nearly all the atmospheric services will see an increase in usage (Table I) as the global population rises.

4. Conclusion

The valuation of atmospheric services at between 100 and 1000 GWP is undoubtedly an underestimate and further research is required to develop more systematic and sophisticated valuations for each of the 12 individual atmospheric services. It is clear that the atmosphere is the most precious natural resource and that it needs careful protection from exploitation and commodification (Thornes and Randalls, 2007). There is an urgent need to pull together existing atmospheric regulations relating to airspace, air quality, acid rain, ozone depletion and climate change to establish a 'Law of the Atmosphere' for the global 'Atmospheric Commons'. Not surprisingly climate change and increases in severe weather, heat waves, floods, droughts, rising sea levels, melting ice and consequential elevated mortality and threats to biodiversity create difficult problems for policy makers. A better understanding of atmospheric services could be used to force carbon prices (taxes) to reflect the cost of climatic impacts more accurately, which could then provide funds for a 'sky trust' (Barnes, 2001) to offset the costs of adaptation to climate change. It can also lead to a reconsideration of the global equity implications of climate change, since the services identified are underpinned by a geographical unevenness that could be associated with particular distributional effects if the services are adequately considered. Estimates of the total economic cost of geoengineering schemes cannot be relied upon without considering the likely impact on all 12 atmospheric services.

Scientific research has made strong progress in understanding the immense value of the atmosphere to human society. However, that understanding needs to be more widely shared if policies for the sustainable management of the atmosphere are to emerge. This paper presents a new method to summarize and communicate that value to policy makers and the general public. The method is by no means perfect, but the results make it perfectly clear how important the atmosphere really is, by adopting an economic language that can be more easily assimilated into decision-making. That said, an economic approach is clearly limited in terms of communication because it risks turning the atmosphere into a commodity and promoting a solely rational management. Nieman's picture highlights that the value of the atmosphere can also be expressed through art. It is perhaps these artistic representations as much as monetary values that will really engage citizens with their atmosphere.

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